Space Technology Research Grants

NEMS Oscillators as Sensors and Actuators: Understanding the Mechanical Properties of Nanoresonators and Their Applications for Molecular Sensing

Completed Technology Project (2011 - 2015)

Project Introduction

Development of nanotechnology and enhancement of nanostructures for future applications requires a good understanding of a material's behavior at the nanoscale, as it differs from that at the bulk size. Specially designed In-Situ Transmission Electron Microscope (TEM) holders for this task [i.e. Scanning Tunneling Microscope (STM)-TEM and TEM-Atomic Force Microscope (AFM)] allow a materials' behavior and responses to applied mechanical stress and electric fields to be studied. These In Situ STM-TEM and TEM-AFM techniques can be used to address questions regarding the electrical and mechanical stability and capability of materials with high resolution. To our specific interest, we would like to study the mechanical behavior of Nanoelectromechanical Systems (NEMS) oscillators for sensors and actuators applications. The proposed work will study two materials for NEMS oscillators: Silica Nanorods and amorphous-Carbon (a-C) multi branched nanostructures (Nanotrees). The following goals will work includes: To grow fractal multibranched carbon nanostructures and silica nanorods by novel e-beam irradiation techniques developed in our laboratory, To conduct TEM-AFM measurements to obtain their mechanical properties. Deformation forces versus displacement will be measured to directly obtain Young's modulus, Stress, Strain, and Bending Modulus, among others. Mechanical response of Silica Nanorods will be monitored at different e-beam doses. Mechanical properties for a-C Nanotrees are expected to be studied at NASA Langley Research Center, under the supervision of Jae-Woo Kim, during the summer of 2011. To use the STM-TEM holder and a radiofrequency source to find the resonance frequencies. For this, two approaches will be used: first, to use a piezoelectric microdevice specially designed for these experiments, and second, to use polarization of an STM tip. Silica Nanorods and a-C Nanotrees will be grown In Situ at the tip of a porous silicon film inside the TEM. Resonance (or near-resonance) frequencies will be determined, in both approaches, by direct monitoring of the nanostructure's oscillation response. Experimental resonance frequencies and Q factors will be obtained. Mechanical properties, such as bending modulus and Young's modulus, will be determined from the structures' resonance frequencies, indirectly. To conduct graphitization studies of a-C Nanotrees, by applying a current on the nanotree's branches and thus heating it. This heating is predicted to cause some reorganization of the atomic structure, thus changing the a-C into graphite. Mechanical and electrical properties will be measured for the a-C/Graphite Nanotrees. Our expected outcomes are to combine novel growth techniques and direct in-situ TEM measurements to understand the electrical and mechanical properties of silica nanorods and fractal carbon nanostructures for the development of novel ultrasensitive nanoresonator detectors. In particular: the use of novel growth method for silica nanorods will allow us to tailor its dimension and final shape with nanoscale accuracy to tune resonance frequencies and form silica-based multi-frequency nanoresonator detectors, exploit the fractal structure of multibranched carbon nanofibers to minimize

Project Image NEMS Oscillators as Sensors and Actuators: Understanding the Mechanical Properties of Nanoresonators and Their Applications for Molecular Sensing

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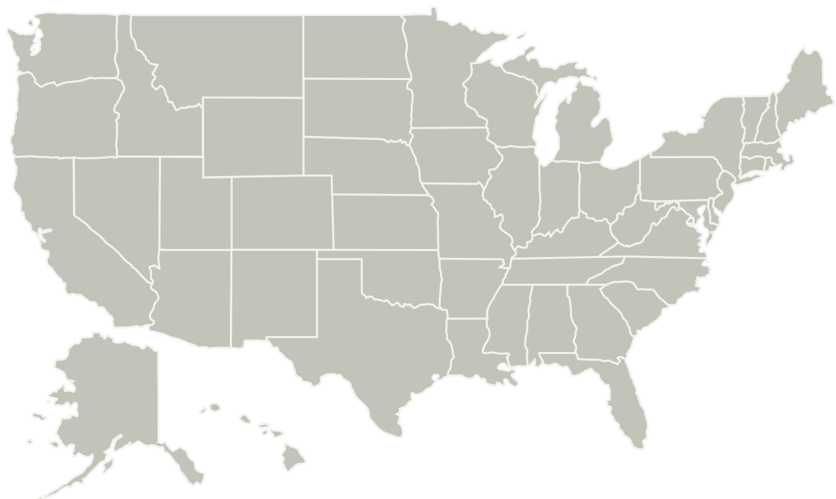
steric effects and develop highly sensitive bio- and chemical sensors. These ultrasensitive resonators can serve as sub-microgram sensors by observing the structure's resonance frequencies. Also, TEM-AFM measurements will provide understanding about the mechanical response of materials at the nanoscale that could guide new developments in nanosensors and actuators technology.

Anticipated Benefits

These ultrasensitive resonators can serve as sub-microgram sensors by observing the structure's resonance frequencies. Also, TEM-AFM measurements will provide understanding about the mechanical response of materials at the nanoscale that could guide new developments in nanosensors and actuators technology.

Primary U.S. Work Locations and Key Partners



Primary U.S. Work Locations
Puerto Rico

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

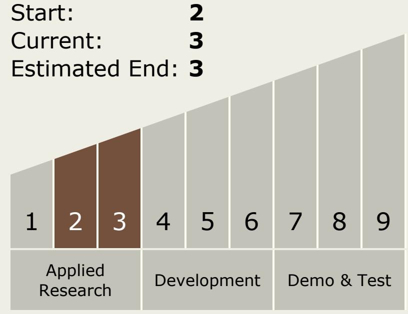
Luis F Fonseca

Co-Investigators:

Jennifer Carpena
Jennifer Carpena Nunez

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Images

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Project Image NEMS Oscillators as Sensors and Actuators: Understanding the Mechanical Properties of Nanoresonators and Their Applications for Molecular Sensing
(https://techport.nasa.gov/image/1804)

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Technology Areas

Primary:

- TX12 Materials, Structures, Mechanical Systems, and Manufacturing
  └ TX12.1 Materials
    └ TX12.1.6 Materials for Electrical Power Generation, Energy Storage, Power Distribution and Electrical Machines